Development of airtightness of Estonian wooden buildings

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INTRODUCTION

In Estonia, lightweight timber-frame envelopes are common for single-family detached houses. Structures built from timber logs have been historically very common and are still used for some projects. It is expected that the airtightness of the building envelope has been improved over the years, especially after the minimum requirements for energy efficiency have been set by legislation in 2008.

Previous research has shown that the overall air leakage of the building envelope depends mostly on the quality of the building process and subsequent factors directly affecting it. There have been attempts to estimate the airtightness of the building envelope based on component measurements, but no reliable method for estimation has been found. Therefore country specific baseline values have to be determined based on existing building stock.

METHODS

The field measurements of airtightness in Estonian detached and apartment buildings conducted between 2003 – 2017 were combined into a large dataset (313 buildings) for further analysis (standardised pressurisation testing, method B). The buildings were grouped by:

- building structure,
- construction technology,
- number of storeys,
- year of construction (divided to "age groups"),
- energy classification,
- compactness factors of the building envelope,
- companies with systematic measurement practice.

Average (median) air leakage rates at 50 Pa (q_{50}) were determined with 0.16 and 0.84 quantiles and tested for significant differences within the grouping factors. For use in whole building energy calculations the estimation of the base value of air leakage rate ($q_{50,base}$) for each grouping factor with a 75% margin and 84% confidence interval was calculated according to the method described in the Finnish quality assurance manual for airtightness of building envelope (*RT 80-10974, 2009*):

$$q_{50,base} = q_{50,mean} + 0.674 \cdot \sigma_{q50} + \sigma_{q50} \ : \sqrt{n}$$

where: $q_{50,base}$ – estimated base value of air leakage rate (m³/(hm²)); $q_{50,mean}$ – measured value of mean air leakage rate; σ_{q50} – standard deviation of mean air leakage rate; n – number of measured buildings in the group considered.

RESULTS

As expected, the median air leakage (q_{50}) of older buildings in range 10.7 – 13.9 m³/(hm²) has decreased to 1.1 m³/(hm²) after the minimum requirements for energy efficiency have been set (figure 1). The results of more detailed analysis for this group is given in table 1.

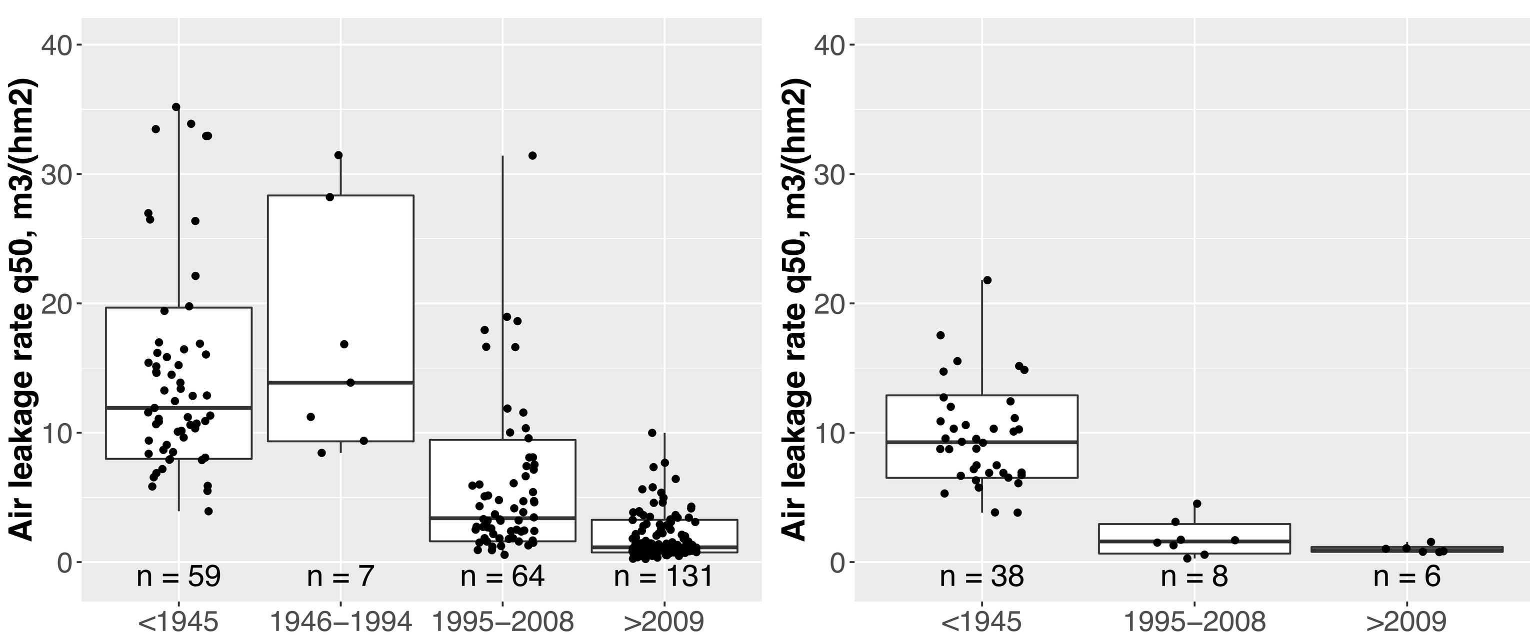

Figure 1. Air leakage rates (median values with 0.16 / 0.84 quantiles) of detached (left) and apartment buildings (right) based on year of construction.

The quality of workmanship through systematic measurements as well as prefabrication showed significant improvement of airtightness corresponding to a 37% to 74% reduction in air leakages, depending on the factor and grouping.

Table 1. Effect of different factors on air leakage rate and its distribution

	number of buildings	Air leakage rate q_{50}, m³/(hm²)					
		median	16% percentile	84% percentile	mean	σ_{q50}	$q_{50,base}$
All wooden buildings							
<1945	97	10.7	6.9	16.4	12.5	6.9	17.8
1946-1994	7	13.9	9.3	28.3	17.1	9.2	26.8
1995-2008	72	3.2	1.5	8.1	5.2	5.5	9.5
>2009	137	1.1	0.8	3.1	1.8	1.6	3.0
subset of wooden buildings 2009+							
energy class A	6	0.5	0.3	1.5	0.9	1.0	2.0
energy class B	10	0.7	0.4	1.4	1.0	1.1	2.1
energy class C (minimum)	121	1.2	0.8	3.3	1.9	1.7	3.2
log-building	46	2.2	1.0	3.9	2.5	1.7	3.9
lightweight timber	91	0.9	0.7	1.6	1.4	1.5	2.6
irregular measurements	35	2.8	0.9	5.5	3.1	2.4	5.1
systematic measurements (>5)	102	1.0	0.7	2.1	1.3	0.9	2.0
subset of all log buildings 2009+							
handmade logs	13	3.6	2.7	5.8	4.2	1.9	5.9
prefabricated logs	33	1.6	0.9	3.1	1.9	1.1	2.8
irregular measurements	11	3.0	1.9	6.3	3.9	2.3	6.1
systematic measurements (>5)	35	1.9	0.9	3.5	2.1	1.2	3.1
subset of all lightweight timber buildings 2009+							
prefabricated elements	80	0.9	0.7	1.3	1.1	0.7	1.6
on-site building	11	3.4	1.4	6.0	4.0	2.7	6.7
irregular measurements	24	1.7	0.8	4.6	2.7	2.4	4.8
systematic measurements (>5)	67	0.9	0.7	1.3	1.0	0.4	1.2

The differences in other grouping factors were smaller, although the lightweight timber construction had significantly lower air leakage compared to log houses, even in the case of systematic measurements (figure 2).

Surprisingly, there was no significant difference between buildings regarding the compactness factor of the building envelope and number of storeys.

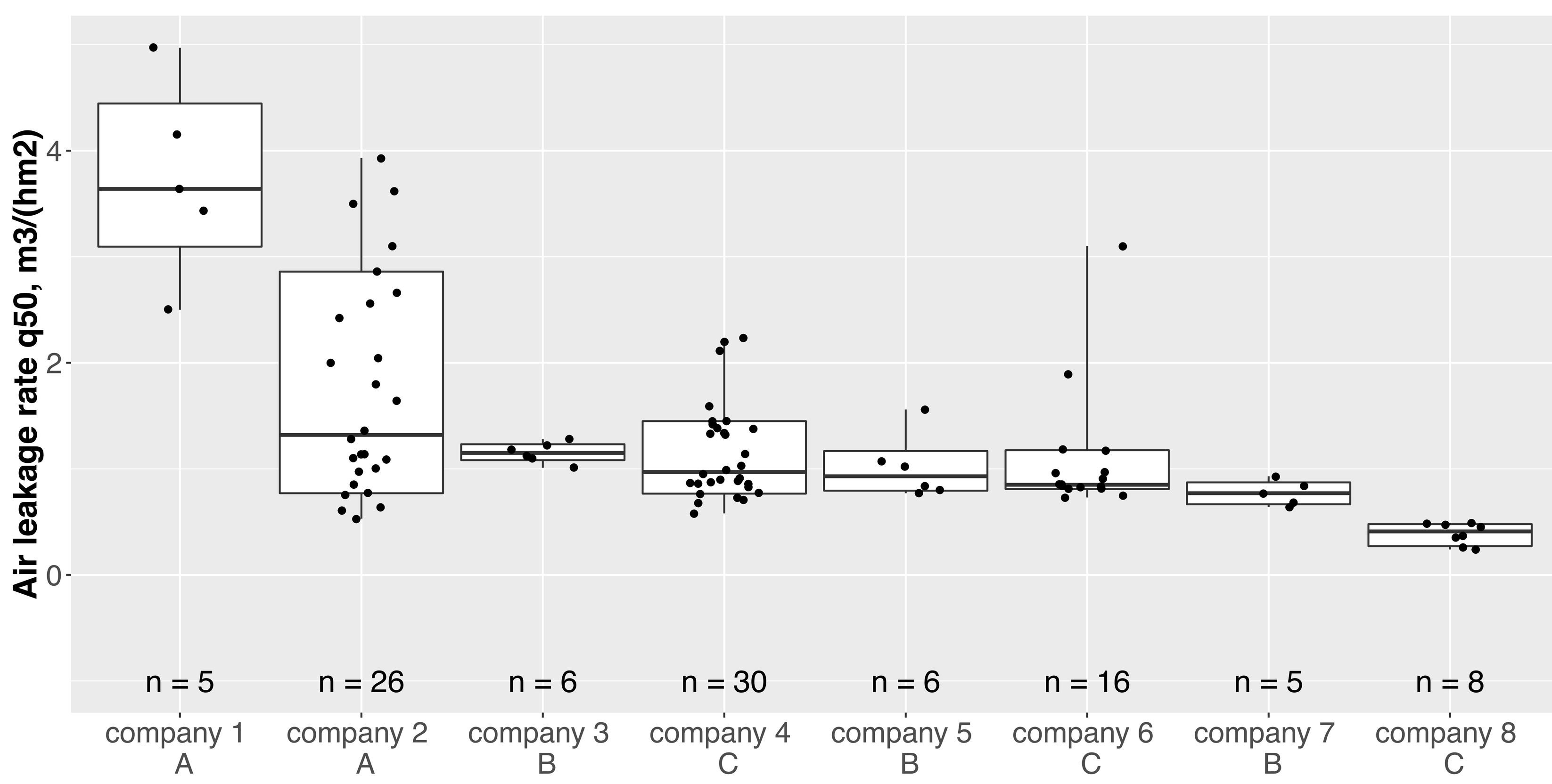

Figure 2. Comparison of air leakage rates and its distribution between companies that conduct systematic measurements (A – log buildings, B – volumetric prefabricated modules, C – prefabricated wall/roof elements).

Assuming consistency in construction technologies and in quality assurance mechanisms, these average values with appropriate safety margins can be used for energy calculation in Estonian conditions for new buildings, or buildings in respective age groups. Due to the high variation in measured values, the base values are much higher than median air leakage rates.

CONCLUSIONS

The airtightness of Estonian wooden buildings has improved by a factor of 10 since the minimum requirements for energy efficiency have taken effect. Buildings with a higher energy efficiency target have a slightly better air leakage rate. Prefabrication with lightweight timber construction technology seems to be superior to traditional log-wood building and notably, prefabrication improves airtightness even within log-wood building or lightweight building groups, meaning that on-site building or the use of handmade logs corresponds to significantly higher air leakages.

The compactness factor and number of storeys did not have a significant effect on air leakage referring to the fact that if systematic quality assurance with a proper air tightness concept is used, the geometric and structural complexity of the building envelope is no longer a key factor while achieving airtightness.

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